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Optimization of mandibular fracture treatment

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CHAPTER 1

INTRODUCTION AND AIM OF THE THESIS

INTRODUCTION

Management of mandibular fractures has a long and extensive history. The first known description of mandibular fracture treatment is described 1600 BC in an ancient Egyptian medical text known as the “Edwin Smith Papyrus”¹. From this time till the 19th century, mandibular fractures were mainly immobilized with head-to-jaw bandages after manual repositioning of the fractures. From the 19th century, the management of mandibular fractures focused on restoration of the occlusion. Simultaneously, management of the fractures shifted from general surgeons to the oral and maxillofacial surgeons. Many intra- and extra-oral splints and circum-mandibular wiring techniques were introduced and modified to immobilize the fractures. For instance, the Gunning splint (by Thomas Gunning), wire ligatures (by Gurnell Hommond), re-introduction of intermaxillary fixation (by Thomas L. Gilmer), Angle’s apparatus (Dr. Angle), and the Ivy loop (Robert H. Ivy) were introduced during the 19th century¹. All these methods were *closed treatments* of the mandibular fractures. The definition of terms “closed” and “open” treatment of the mandibular fractures has been controversial around the world. According to the consensus article by Bos et al.² closed treatment is defined as any treatment that does not involve an open surgical exposure of the fracture whereas open treatment means surgical exposure of the fractures, reduction and fixation². Closed treatment is still applied in certain cases of mandibular fractures, particularly for the treatment of incomplete fractures, high condylar fractures, and a selection of non-displaced, immobile fractures.

To achieve uncomplicated fracture healing with *open treatment*, the following three factors must be considered:

1. Vascularization. The cranio-maxillo-facial region is the most vascularized region of the body, but the mandible is less vascularized than the midface region. The major blood supply of the mandible is provided by the lingual, facial and inferior alveolar arteries.
2. Adequate anatomical reposition (reduction). Reduction of the fractured mandible is crucial to achieve uncomplicated fracture healing. Reduction is the action of reestablishing a fracture by returning the affected segments of the mandible to their normal anatomical position.

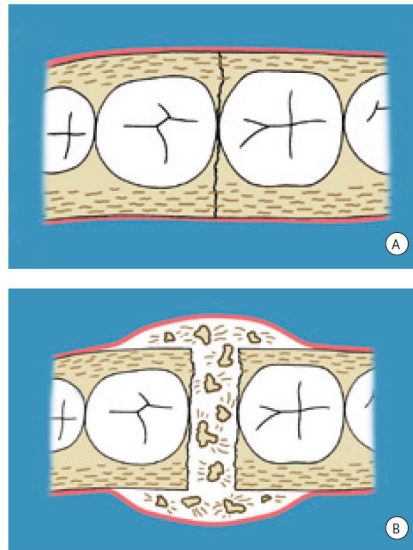


Fig 1. Schematic drawing of bone healing. A, Primary bone healing with direct bridging of the fracture through Haversian canals. B, Secondary bone healing through callus formation.

3. Immobilization by means of internal fixation. Open reduction is performed with surgical intervention and it is always followed by immobilization of the fracture. Immobilization has been routinely managed by internal fixation.

Stable immobilization leads to primary bone healing without callus formation. Conversely, if immobilization is not rigid enough, the fracture may heal by secondary healing which means that callus formation will occur (Fig 1). Besides these factors, other factors such as the patient's age, general health, and type of fracture will influence the healing.

Surgical instruments like clamps or forceps have played an important role in the history of traumatology from 1600BC to recent years³. The first known pivot joint forceps were introduced by Charriere (1845)^{3,4}. Subsequently, this pivot joint design was modified as a fracture holding forceps, by Faraboeuf and Lambotte³. Since then, all kinds of modifications have been made, and reduction forceps are routinely used in the modern practice of trauma surgery. The main function of a fracture holding forceps is to secure a firm grasp on the fracture segments in order to get an anatomical reduction of the fracture

without damaging soft tissues and bone allowing comfortable and precise fixation of the fracture. In this manner, fracture fragments can be optimally reduced to enable primary bone healing. The development and use of fracture reduction instruments has mainly been restricted to the field of general trauma surgery and orthopaedic surgery. The role of these instruments in mandibular fracture treatment has been modest. So far no attempt has been made to estimate the benefits and pitfalls of fracture reduction forceps in mandibular fracture treatment. The first goal of this thesis was to review currently available mandibular fracture reduction/alignment methods. This was done with the idea that optimal fixation of a fracture can only be achieved after optimal reposition.

Nowadays, fixation of a mandibular fracture is always achieved by applying one of the available plate and screw systems. In 1886, the German surgeon Hansmann was the first to invent the plate-screw-system for fixation of bone fragments. Much later Luhr⁵ (1968) introduced the vitallium compression plate osteosynthesis for mandibular fractures, which had eccentric holes and screws with a conical head while the plates were shaped like a half-pipe surrounding the lower body of the mandible. Since then, numerous plate and screw systems have been introduced and applied for fracture fixation⁶.

Principally, an osteosynthesis of the mandible can be categorized as 'load bearing' or 'load sharing'. Load bearing plates (also called reconstruction



Fig. 2. A, Regular mini-plate and self-tapping screw. B, Mini-locking-system plate and self-tapping locking screw (Synthes, Umkirch, Germany), *Sauerbier S et al. 2008*⁶.

plates) are applied when the osteosynthesis system has to withstand all the functional forces at the fracture site. Load-bearing plates are applied in case of complex comminuted fractures, infected fractures, and fractures of a severely atrophic mandible. The dimension of these plates is usually rather coarse. In contrast, the smaller load sharing plates distribute functional forces between plate and bone. Generally, these plates are known as a mini-plates (Fig 2A). As a result of their smaller size they are suitable in cases where, after reduction, interfragmentary stability of the repositioned fragments contributes to the stability of the fracture as a whole. This principle of load sharing fixation only works if the mini-plates are placed in the so-called tension zone. This was made clear during the first attempts to fixate a mandibular fracture with mini-plates. Brons and Boering⁷, applied small finger plates developed for hand surgery⁶. However, they inserted the plates at the lower border of the mandible which was biomechanically unfavorable. Subsequently, Michelet et al. and Champy et al.^{8,9} developed the mini-plates systems, and contributed enormously to the understanding of the biomechanical characteristics of the mandible. The Champy's principle was invented based on the previously introduced surgical device, the mini-plate. It shows that after careful investigation, sometimes it is possible to develop the new surgical techniques by considering surgical instruments.

Another basic concept of osteosynthesis is the locking plate system (Fig 2B). The distinctive feature of the locking plate system is that the screw head itself is threaded and locks firmly into a thread in the plate hole, and so works like an external fixation¹⁰⁻¹². The locking plate systems are available for both load bearing and load sharing plates. Hypothetically, the advantages

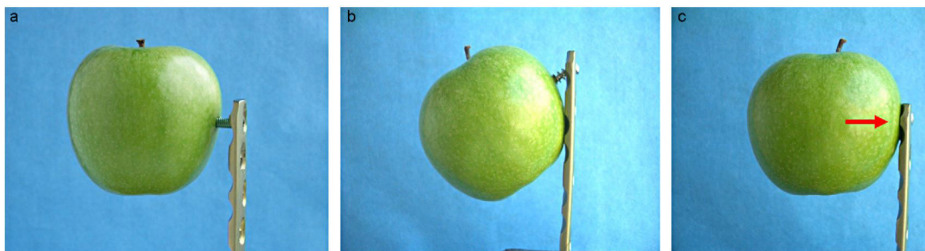


Fig 3. Fixation of an apple on a plate. (A) With a locking screw, the assembly is stable. (B) With an untightened conventional screw, the assembly is unstable. (C) Compression is necessary against the plate, *Cronier et al. 2010*¹⁰.

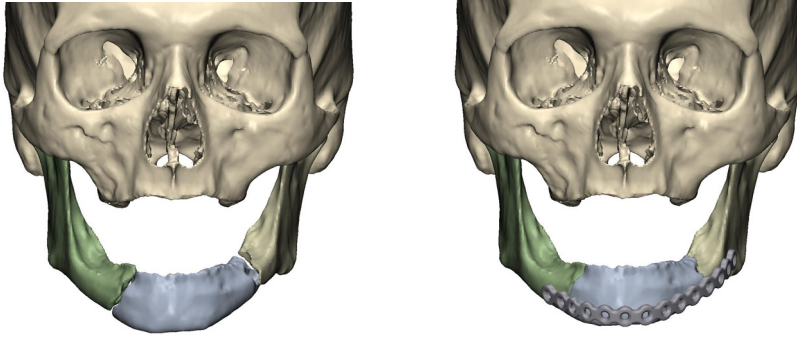


Fig. 4. An example of virtual preoperative planning of the atrophic mandibular fracture.

of a locking plate system over a conventional plate system are less screw loosening, greater stability, while less accuracy is required in plate adaption (Fig 3). Although there are many reports in the literature on the outcome of a locking plate system, most are restricted to biomechanical studies, particularly in mandibular fractures^{13–16}. While some clinical studies also tend to favor the use of a locking plate system in mandibular fractures, other clinical studies did not find a difference with regard to postoperative complications^{17–21}.

Open reduction is facilitated by all instruments and osteosynthesis materials that have been developed in the past century. In addition, the methods for surgical access to the fractures have been improved. A more recent development is the possibility of pre-operative planning of complicated fractures (Fig 4). This development also contributes to anatomical reduction and stable fixation of the fractures.

However, the ultimate goal of the treatment of a fractured mandible is not only to restore the anatomy, but also the function. Although techniques and materials for open reduction have been improved continuously there is still room for closed treatment, especially in cases of fractures of the condylar process. Should these be treated open or closed?

Moreover the management of fractures of the edentulous and severely atrophic mandible is still controversial. It is possible that ongoing discussions on closed versus open treatment are caused by a lack of consensus on the exact

diagnosis. Recently, three-dimensional analysis of fractures of tibial plateau and acetabular and as well as radial head fractures has been developed for general trauma surgeons, which provide additional information about the fracture extent and quality of the postoperative reduction²³⁻²⁵. The same method could be applied on mandibular fractures in order to reach an undisputable 3D fracture diagnosis that could help to evaluate treatment outcome. Ultimately this could lead to a better consensus about choices for open and closed treatment.

AIMS OF THE THIS THESIS

Although the outcome of mandibular fracture management is generally satisfactory there still is room for improvement. The general aim of this thesis was to evaluate fracture reduction/alignment methods including reduction forceps, plate and screw systems, treatment modalities for the edentulous and severely atrophic mandible fractures, and to analyze the condylar process fracture characteristics using three-dimensional methods.

To be more specific:

- to review currently available mandibular fracture reduction/alignment methods (Chapter 2)
- to evaluate fracture reduction/alignment methods and their influence on postoperative complications (Chapter 3)
- to design and develop sophisticated fracture reduction forceps and to test their feasibility (Chapter 4)
- to review the cons and pros of locking and non-locking plate systems (Chapter 5)
- to assess the management of fractures of the edentulous and atrophic mandible (Chapter 6)
- to analyze characteristics of condylar process fractures, based on a three-dimensional analysis (Chapter 7)

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Siberian musk deer (Moschus moschiferus), Credit: Hureelen/ Ganbayar Urtnasan